Asian Journal of Research in Agriculture and Forestry

Volume 9, Issue 4, Page 276-282, 2023; Article no.AJRAF.108925
ISSN: 2581-7418

Revolutionalizing Forest Monitoring and Conservation Using Internet of Things (IoT): The Challenges and the Opportunities

Wealth Abiola Samuel [a*], Irunokhai Eric Aghiomesi [b], Ademola Samuel Adedeji [b], Smart Deborah [a], Adepoju Oluwatosin Victoria [a], Aladeokin Blessing Oluwaseun [a] and Ayanniyi Oluwadamilola Aduragbemi [a]

[a] Onigambari Research Station, Forestry Research Institute of Nigeria, Nigeria.
[b] Basic and Computer Science, Federal College of Wildlife Management, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJRAF/2023/v9i4256

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/108925

Review Article

Received: 22/09/2023
Accepted: 29/11/2023
Published: 06/12/2023

ABSTRACT

Over some decades, advancement has come to the way forest is being monitored. The process of monitoring the forest area have advanced beyond human-power into technology. Nigeria forests have experience degeneration from illegal logging to encroachment resulting from population growth and agricultural activities. The wildlife species are endangered due to human illegal activities in the forest area. Manual monitoring has achieved some results in keeping the forest safe but there is a need for more effective and real time forest monitoring. Therefore, digital technology

**Corresponding author: E-mail: theabiolawealth@gmail.com;*

should be analyzed for monitoring. Many forests departments in some countries have shifted to the Internet of Things (IoT) devices for real-time forest monitoring and conservation. IoT devices are devices that utilizes sensors to capture information about activities going on in the forest area and alert the monitoring personnel of any illegal activities through an electronic device connected to computer. IoT system collect data from the forest and send them to the cloud server for storage and analysis of activities that are going on in the forest area. This have helped forest officers in curbing many issues like illegal logging and forest fires. It has also helped in conserving wildlife within the forest. This paper discussed some IoT devices for real time forest monitoring and conservation. This manuscript also discussed the components of IoT devices and how they benefit forestry.

Keywords: Forest monitoring; internet of things; digital technology; sensors.

1. INTRDUCTION

"Forests play an important role in climate change mitigation, protection of the soil from erosion, and in provision of wildlife habitat. Forests are the biggest absorbents of fossil fuel caused carbon dioxide (CO_2) emissions" [1]. Therefore, it is very important to monitor forests. Internet of Things is a new technology which has an enormous role to play in the forest ecosystem management and stability. It will help tremendously to prevent forest soil degradation, prediction of forest fire, protection against illegal logging and in the conservation of species and habitats. The IoT hold strong promise for digital forestry [2] applications. "IoT has found its utility in transportation, environmental monitoring and forecasting, home and office appliances, agriculture, health, security, and energy conservation" (Bamigboye and Ademola 2016). Over the past few years, developing countries had started adopting the technology benefit of the Internet of Things. This ranges from its implementation in sectors like finance, agriculture, healthcare, forestry, electricity, and beyond. The adoption is of great advantage in socioeconomic advancement of the emerging countries. For example, the introduction of smart meters to properly organize and monitor the energy consumption of households appliances. The introduction of wearable sensor watches and bracelet to monitor the health status of human being. Development organizations, businesses and citizens in the emerging world are already incorporating the IoT and Big Data analysis to help alleviate some of the developing world's most important problems (ITU). In this paper, we have arranged the sections for the discussion on Degradation of forests in Nigeria, the Internet of Things and its implementation in the area of forest monitoring. History of Internet of Things, benefits of Internet of Things in forest monitoring, components of IoT devices are elaborated in the work.

2. DEGRADATION OF FORESTS IN NIGERIA

Nigeria is one of the most populated country in Africa, with a total population of 162.5 million people. Nigeria is enrich with large expanse of forest land, the swamp forest in the extreme southern part of the country, the tropical rainforest in the southwestern axis and the wooded Savannah in the middle belt [3]. FAO [4] reported about Nigeria that forests occupy about 10 million hectares, which is almost 10% of the total land area of 92,377 hectares. According to the report of Global Forest Watch in 2022 Nigeria has lost 105,000 hectares of natural forest. 166,000 hectares humid primary forest, and 1.25 million hectares of tree cover. Records from the Department of Forestry shows that Nigeria has a total of 1,160 constituted forest reserves covering a land area of about 1075km^2. For over 3 decades now, Nigeria's forests region have continued to degenerate due to population growth, agriculture and illegal logging. According to Batta, et al. [5] Nigeria continually loses its forest cover at an annual rate of 3.5% and this result to a loss of 3,500–4,000 km^2 of forest land per year. This situation is expected to deteriorate further in the future if adequate conservation measures are not properly introduced [6]. Regional breakdown of changes from 1979 to 1995 shows that the total forest declined by 48% in the north central, 7% in the north east, 60% in the north west, 53% in the south east, 13% in the South-South (Nzeh,et al. 2015) geopolitical region of Nigeria. The major problem facing the forest sustainability in Nigeria is illegal logging and encroachment. illegal logging is a major problem for many timber-producing countries in the developing world. It causes environmental damage, costs governments billions of local currencies in lost revenue, promotes corruption, and undermines the rule of law and good governance [7,8]. illegal logging will continue until there an introduction of modern technology

for forest monitoring in Nigeria. Manual process of forest monitoring had delivered results to some extent. However, human personnel cannot be in the forest all day long but new technology can deliver real time monitoring. One of such technology is the IoT device which is reliable, efficient and cost effective for forest monitoring and conservation.

3. A BRIEF SUMMARY OF THE INTERNET OF THINGS

The Internet of Things (IoT) is an instrumentality designed to work in the information technology ecosystem as a coherent entity with the ability to combine interrelated devices which are either connected to a network and/or to one another, transferring data without necessarily requiring human-to-machine interaction. in simple terms, IoT is a set of electronic devices that can share information among themselves. IoT devices are termed smart devices because they possess sensors and can transmit complex data ~~analytic~~. IoT devices receive information using sensors and offer services to the user based on the analyses of that information following user-defined parameters (Wealth et al. 2023).

(Arthur Ume, et al. 2018) defines “The Internet of Things (IoT) as the network of physical objects or "things" embedded with electronics, software, sensors, and network connectivity, which enables these objects to collect and exchange data. IoT allows objects to be sensed and controlled remotely across existing network infrastructure, creating opportunities for more direct integration between the physical world and computer-based systems, and resulting in improved efficiency, accuracy and economic benefit. A thing, in the Internet of Things, can be a person with a heart monitor implant, a farm animal with a bio-chip transponder, an automobile that has built-in sensors to alert the driver when tire pressure is low or any other natural or man-made object that can be assigned an IP address and provided with the ability to transfer data over a network”.

The IoT can also be define in terms of functionality, sensitivity and connectivity. Functionality in the light of execution, quality of delivery, dependability, strength, adaptability, power supply, scalability, and the ability to exchange usable information easily. Sensitivity in aspect of utilizing sensors to collect data from physical, chemical, and environmental factors. After which it transmits the collected data through wireless connection to a cloud server. Such wireless communication devices include Zigbee, bluetooth, wifi and LoRa. IoT devices are either connected to the internet directly or indirectly through another IoT device, or both. This internet connections enhances the sharing of captured information with users to enable them make important decision. “The purpose of the IoT concept is to transform the real world and every day electronic devices, appliances, etc., into intelligent interconnected virtual objects. By keeping the user informed on the state of things and giving the users control of things, a better global humans-devices-humans communication can be achieved” [9]. “The IoT creates linkages and connections between physical devices by incorporating software applications. IoT devices can enable users to access information or control devices from anywhere using a variety of internet-connected devices. For example, a smart doorbell and lock may allow a user to see and interact with the person at the door and unlock the door from anywhere using a mobile device or computer” [10]. “The IoT is also being used for asset optimisation such as plant, machines and vehicles supporting proactive maintenance, capacity planning and safer operating environments” [11].

4. BENEFIT OF IOT IN FORESTRY

PricewaterhouseCoopers (PwC) describes the IoT as “transforming everyday physical objects that surround us into an ecosystem of information that will enrich our lives.” The concept of IoT in forest monitoring and conservation is to enable real-time transmission of collected data through wireless communication system. The data collated from the forest sites based on physical, environmental, chemical, and biological components are thereby transmitted to the cloud for storage, where the end users can have access to it through the visual interface for real-time forest monitoring. This will help them in decision making process towards future preservation of the forest sites. The following are the areas where IoT devices are been deploy for real time forest monitoring and inventory:

4.1 Illegal Logging Monitoring

One of the significant causes of deforestation in Nigeria is logging, which can be either through legal or illegal mediums (DGB Group 2023). Illegal logging activities has resulted to deforestation and biodiversity loses in forest reserves. The manual monitoring of the forest to prevent unauthorized activities is practically

challenging job. Though sufficient manpower has been made available, it is inefficient because it might be life threatening. (Nirmala 2021). This method of forest monitoring was risky for human life especially in a country like Nigeria where forest reserves northern region are now hideouts and camping sites for insurgents, highway armed robbers, thieves, and other criminals (Suleiman 2014). Illegal logging can be detected through sound sensors with the use of it microphone which have the capacity to capture logging related sounds such as saws, axes, and transportation. The information collected can be transmitted through the wireless communication links in real time to forest control centers for proper enforcement actions [12]. Vibration sensor also help in identifying the sound of tree felling machines like chainsaw sound and it can also identify the sound of a falling tree. All of these would help in controlling the deforestation process. Riaño et al. [13] proposed an acoustic signal evaluation and network node communication system of wireless sensor network to prevent illegal deforestation. Arasvathi et al. [14] proposed "a system consisting of a processing unit (Raspberry Pi) and three sensors: a motion sensor, a temperature sensor, and a gas sensor. The motion sensor is employed to stop the destruction of the system by wildlife. The two environmental sensors (temperature and gas sensors) are configured to detect temperature value and gas concentration". Divya KV et al. [15] proposed a system to measure major parameters within the forest area at regular interval using different interface without human interaction. The collected data will be sent through a wireless communication to central platform where it can be accessed and utilized appropriately by forest personnel. The interface comprises of a sound sensor which detect the chainsaw noise that would emerge during the cutting of the tree. The vibration sensor to sense the frequency of the falling tree is also part of the interface.

4.2 Fire Monitoring

"There are several factors causing wildfire. Some of such factors are the human factor which can either be intentional or accidental and natural reasons. Such as high temperature in a hot summer day or a broken glass working as a collective lens focusing the sun light on a small spot for a length of time thus leading to fire-ignition. Once ignition starts, combustible material may easily fuel to feed the fires central spot which then becomes bigger and wider" [16]. Due to increase in the effect of global warming wildfire will increase and the impact will be great. Therefore, it is necessary to adapt a more effective way to detect and curb forest fire early. Though the fire-tracing and other manual process of securing the forest fire incident has achieve good results but there is a need for real time fire monitoring within the forest sites. The Early detection is the safest way to protect forests against the threats posed by fire. Significant milestones have been achieved in using IoT devices in securing the forest from dangerous fire. Zhang et al. [17] proposes a fire detection system using WSN based on ZigBee, GPRS, and Ethernet communication modules. Wolfgang et al. [18] designed an Unmanned Aerial Vehicle (UAV) equipped with gas sensors and an infrared camera which is flown in a drone to detect an early fire providing detailed picture. Ganesh et al. [19] describe a forest fire detection system based on WSN and on solar energy harvesting modules. It applies a node hopping scheme to reach the data server. Recent developments in information and communication technologies are already having a huge impact, especially forest fire detection systems [20] and this should also be taken advantage for fire monitoring in the Nigeria forest reserves.

4.3 Forest Species and Wildlife Monitoring

Monitoring of wildlife and forest species through the application of IoT devices is the new trend ~~of event~~. Various similar sensors are mounted activated within the forest area to monitor the activities of wild animals. Ecological monitoring in the forest environments is a laborious job for human researchers. Often time such efforts require sitting in the field for hours to record bird's species in forests [12]. Castro et al. [21] developed a monitoring system that has the ability to monitor and listen to multiple bird's sound at a time. This system proffers solution to the problem of long hour human labour to collect data by giving a detailed real-time activity of the birds. Such activity includes the arrival and departure of the bird to and from their nests. It also gives information about their locations and nesting pattern changes. Jun Xu [22] developed animal monitoring and tracking device in wild areas. Sensor identifies animal's appearance by different types of inputs such as smell, sound and image. The deployed sensors help the system to capture animal appearance information in wildlife areas. Kumar [23] designed animal health monitoring and tracking system

which consists of four major sensors; heart rate sensor, temperature sensor, pulse rate sensor and respiratory sensor. It also consists a Global Positioning System which is deployed to track the movement of animals and to find their location. The wireless communication technology is ZigBee because of its very low power consumption, range of 10-3000 meters and its capacity to connect up to 64000 devices at ~~having~~ 50 meters [24]

5. COMPONENTS OF INTERNET OF THINGS

5.1 Sensor

IoT devices are regarded as smart devices because of the sensor embedded within the system to collect, analyse and transmit the data to the server using the wireless communication links. Sensor measurements also aid in the detection and prevention of major natural and human-aid disasters from causing havoc to the forest region real-time monitoring with sound, vibration, pressure, temperature, and weather pattern sensor technology been used to brief and alert the forest officers for a quick decision to be made to halt the action and avert the negative consequence it should have on the forest sites. There are major sensors which are regularly use in forest monitoring activity. They are sound sensor, vibration sensor, humidity sensor acoustic sensor, temperature sensor, Global Positioning System (GPS) sensors which provide information about location [25,26].

5.2 Gateway

This an essential component of IoT that basically act as a bridge between sensors and the server. It grants the sensor the access to transmit the collected data through wireless communication links. This is the medium of transportation that data from the sensor travel through to the server. Examples of this gateway are: cellular network, bluetooth, Wifi, Zigbee and LoRa. The usability of this gateway devices depends on their features, the scalability and the function they are to perform. Range, bandwidth and power consumption must be put into consideration.

5.3 Cloud

This is a very important part of an IoT system which helps in the storage, management and processing of the information captured by an IoT devices. the cloud is a high-performance and advance connection of servers having maximum efficiency to process high-speed data of billions of devices. It is also efficient in distributing analyse data to the user interface for decision making process.

5.4 Analytic

Smart analytic solutions are necessary in IoT system to effectively manage and improve the entire system. It is the process of conversion of data from analog form to digital form. The numerous data generated by smart devices are processed into insightful information which can be interpreted and use for further analysis.

5.5 User Interface

This is the physical part of the IoT system which allow human personnel to access the processed information transmitted from the server. The user interface can be a personal computer or an android phone where the notification of what is going on at the monitored site can be received and work on effectively.

6. CONCLUSION AND RECOMMEND-ATION

Nigeria's forests region has continued to degrade due to encroachment, and illegal logging. Illegal logging remains the major cause of forest degradation in Nigeria and if it continues, it will have great effect on climate change and sustainable forest management will never be achieved. Therefore, in order to preserve the vegetation and protect endangered wildlife, it is recommended that there should be an introduction of real-time technology for forest monitoring. Though manpower monitoring processes have achieved some results but it cannot perform a real time forest monitoring. IoT is a possible solution for implementing real-time monitoring by the integration of IoT modules in the forest. This will help both government and private owners to monitor forest area adequately. It will also help forest officers to receive prompt information about the happenings in the forest area through the IoT designated system.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Saxe H, Ellsworth DS, Heath J. Tree and forest functioning in an enriched CO2 atmosphere. The New Phytologist. 1998; 139(3):395–436.
2. Salam. Subsurface MIMO: A Beamforming Design in Internet of Underground Things for Digital Agriculture Applications, J. Sens. Actuator Netw. 2019;8(3). DOI:10.3390/jsan8030041
3. Ogundele, A, Adebisi O. Deforestation in Nigeria: The needs for Urgent Mitigating Measures, IlLARD International Journal of Geography and Environmental Management. 2016;2(1).
4. FAO. Global Forest Resources Assessment country Report, Nigeria. Food and Agriculture Organization, Rome, Italy; 2010.
5. Batta H, et al. Press Coverage of climate change issues in nigeria and implications for public participation opportunities. Journal of Sustainable Development. 2013; 6(2).
6. Ayeni AO. Forestry in Nigeria: A brief historical overview, phases of development and present challenges, African Association of Remote Sensing of the Environment (AARSE) Special Publication; 2013. Available:https://africanremotesensing.org/forestry-in-nigeria-a-brief-historical-overviewphases-ofdevelopment-and-present-challenges-2/ Accessed on: on 08/11/13
7. Palmer CE. The extent and causes of illegal logging: an analysis of a major cause of tropical deforestation in Indonesia. CSERGE Working Paper, Economics Department University College London and Centre for Social and Economic Research on the Global Environment University College London and University of East Anglia; 2001.
8. Greenpeace International. Buying destruction: A Greenpeace report for Corporate Consumers of forest products. Greenpeace International Amsterdam. 1999a;16-17.
9. Madakam S, Ramaswamy R, Tripathi S. Internet of Things (IoT): A Literature Review, Journal of Computer and Communications. 2015;3:164-173.
10. Patricia Moloney Figliola. The internet of things (IoT): An Overview.Cogress Research Service; 2020.. Available:https://crsreports.congress.gov
11. Barbara Hock, Marie Heaphy, Melissa Evans, Andrew Dunningham and Bryan Graham. The internet of things for forestry: new concepts, new opportunities, NZ Journal of Forestry, February. 2016; 60(4).
12. Abdul Salam. Internet of Things for Sustainable Forestry, Department of Computer Information Technology Technology, Faculty Publications, Purdue University, Paper. 2020;27:147-183.
13. Riaño D, Chuvieco E, Ustin SL, Salas J, Rodríguez-Pérez JR, Ribeiro LM, Viegas DX, Moreno JM, Fernández H, Estimation of shrub height for fuel-type mapping combining airborne LiDAR and simultaneous color infrared ortho imaging, International Journal of Wildland Fire. 2007;16 (3):341–348,
14. Arasvathi, Nahalingham and Chelsea, Ferdyanti Kosasih. Study and Implementation of Internet of Things (IoT) Based Forest Fire Automation System to Detect and Prevent Wildfire. INTI Journal. 2018;1(15):1-5
15. Divya KV, et al. Deforestation Control and Forest Monitoring using Internet of Trees May-June-Int J Sci Res CSE & IT. 2020; 6(3):156-161.
16. Ahmad AA. Alkhatib. A Review on Forest Fire Detection Techniques**,** Hindawi Publishing Corporation International Journal of Distributed Sensor Networks; 2014:12. Article ID 597368, Available:http://dx.doi.org/10.1155/2014/597368
17. Zhang J, Han W, LiN, Kan J. Forest fire detection system based on a ZigBee wireless sensor network, Frontiers of Forestry in China. 2008;3(3): 369–374.
18. Wolfgang Krüll, Robert Tobera , Ingolf Willms, Helmut Essen, Nora von Wahl. Early forest fire detection and verification using optical smoke, gas andmicrowave sensors Procedia Engineering. 2012;45: 584–594
19. Ganesh U, Anand M, Arun S, Dinesh M, Gunaseelan P Karthik R. Forest fire detection using optimized solarpowered Zigbee wireless sensor networks, International Journal of Scientific and Engineering Research. 2013;4:586–596.
20. Hefeeda M, Bagheri M. Forest fire modeling and early detection using

wireless sensor networks, Ad-Hoc and Sensor Wireless Networks. 2009;7 (3-4):169–224.
ITU-T Recommendation Y 2060, note, s 84
21. Castro I, De Rosa A, Priyadarshani N, Bradbury L, Marsland S. Experimental test of birdcall detection by autonomous recorder units and by human observers using broadcast. Ecology and Evolution. 2019;9(5):2376–2397.
22. Jun Xu. Internet of Things Applications: Animal Monitoring with Unmanned Aerial Vehicle, Arvix; 2016.
23. Ratnesh Kumar Choudhary, Internet of things: Wildlife Conservation and its Challenges, Asian Journal of Computer Science and Technology. 2020;9(1):8-13. ISSN: 2249-0701
24. Keertana P. IOT based animal health monitoring & Tracking system using Zig Bee. IJRTI. 2017;2(4). ISSN: 2456-3315
25. Emeka N, Eric E, Nweze NJ. Status and trends of deforestation: An Insight and Lessons from Enugu State, Nigeria Net Journal of Agricultural Science. 2015;3(1): 23-31.
26. Pricewater-house Coopers (PWC) The Internet of Things: Opportunity for the Forest Sector? Owic Executive Innovation Brief. 2015;4(1).

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/108925